# sPHENIX γ-Jet Simulations

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# Last Time

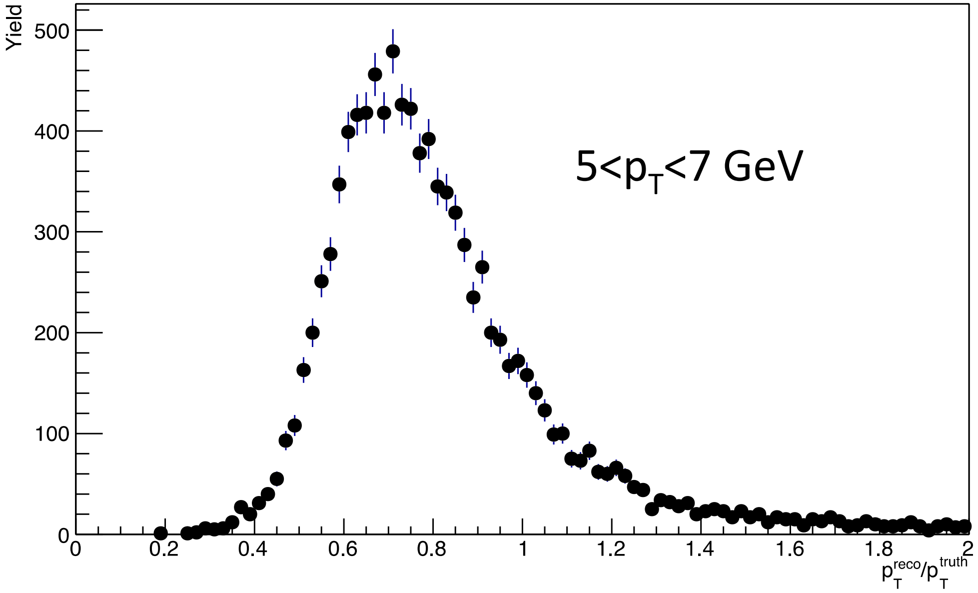
- Last presentation January 17
- Showed first look at photon+jet observables and detector response with Jet Structure Topical Group's PYTHIA files
- Today:
  - Study of jet quantities – how low can we (reliably) measure a jet?
  - γ+jet acceptance and efficiency in sPHENIX
  - Estimate on number of measured γ+jets in sPHENIX
  - Resolution estimate of $\Delta\phi$ and $p_{out}$ at sPHENIX

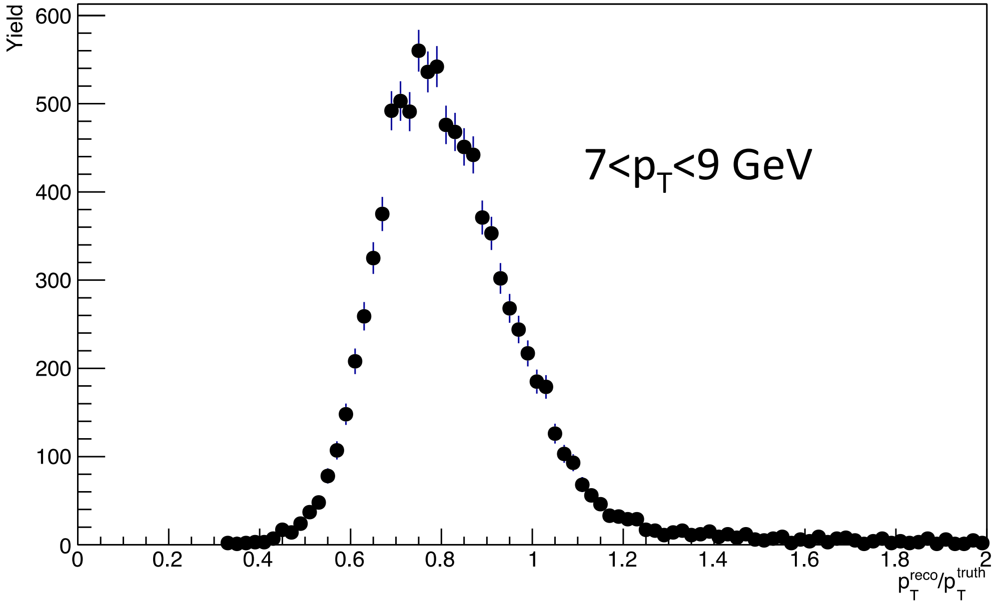
# PYTHIA Requirements

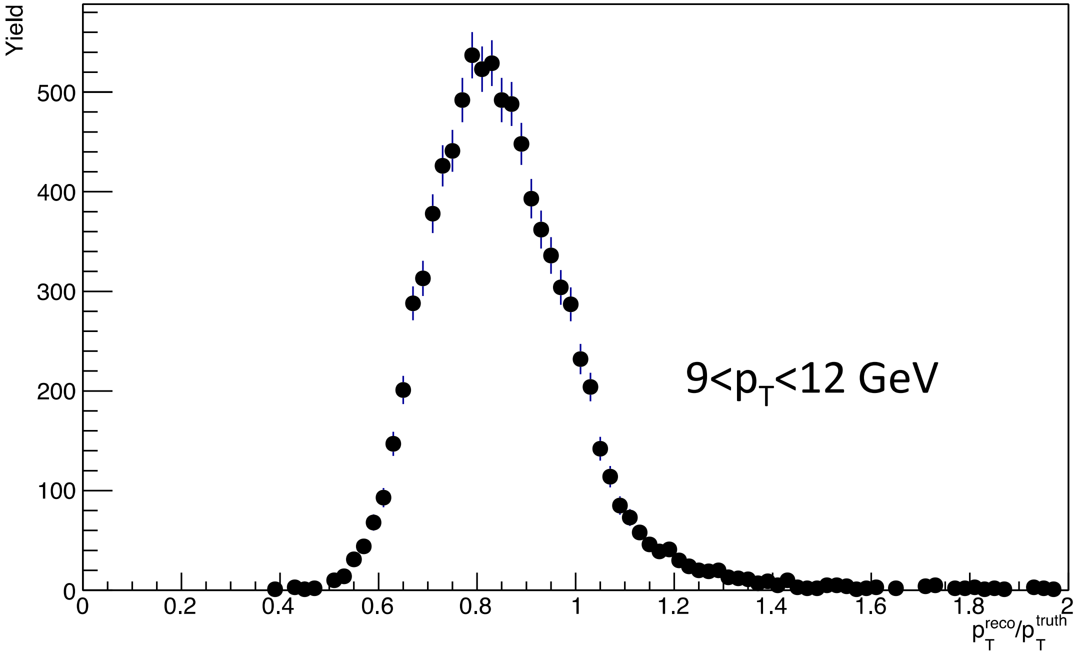
- Using PYTHIA8 simulation, all prompt photon processes on
- Require PhaseSpace:pTHatMin = 10.0 of hard scatter to be greater than 10 GeV
- No other phase space cuts
- Require reconstruction $p_T^{\gamma}$>10
- Unless otherwise indicated jets are reconstructed with the anti $k_T$ algorithm with R=0.4

# Jet Response

# Jet $p_T$ Response

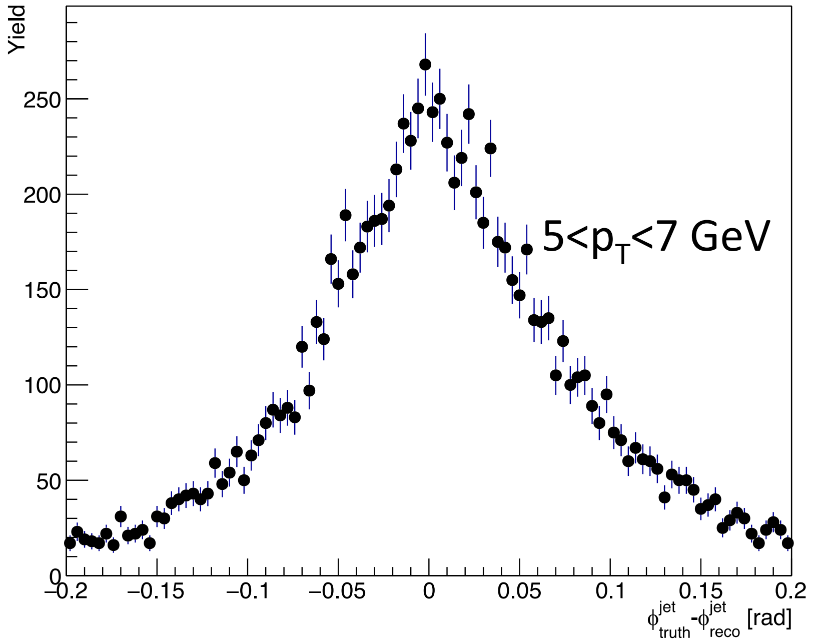


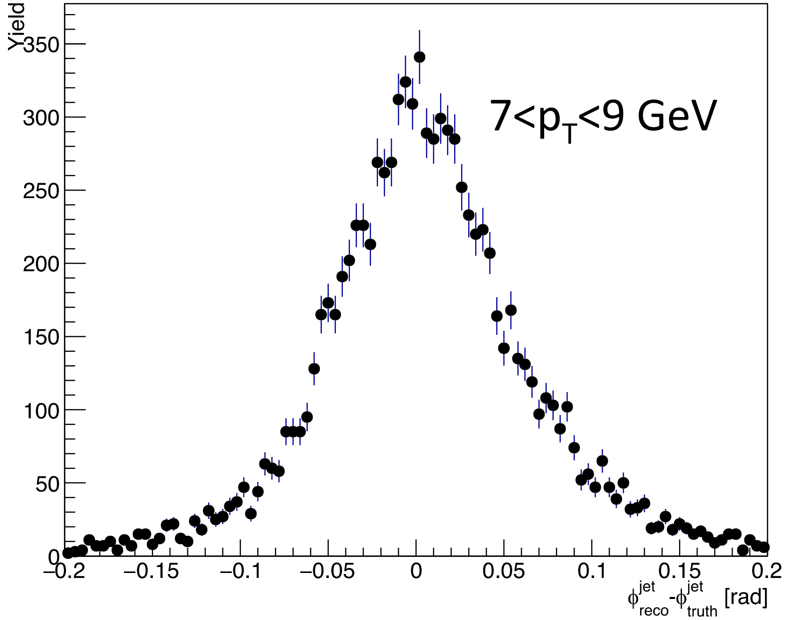



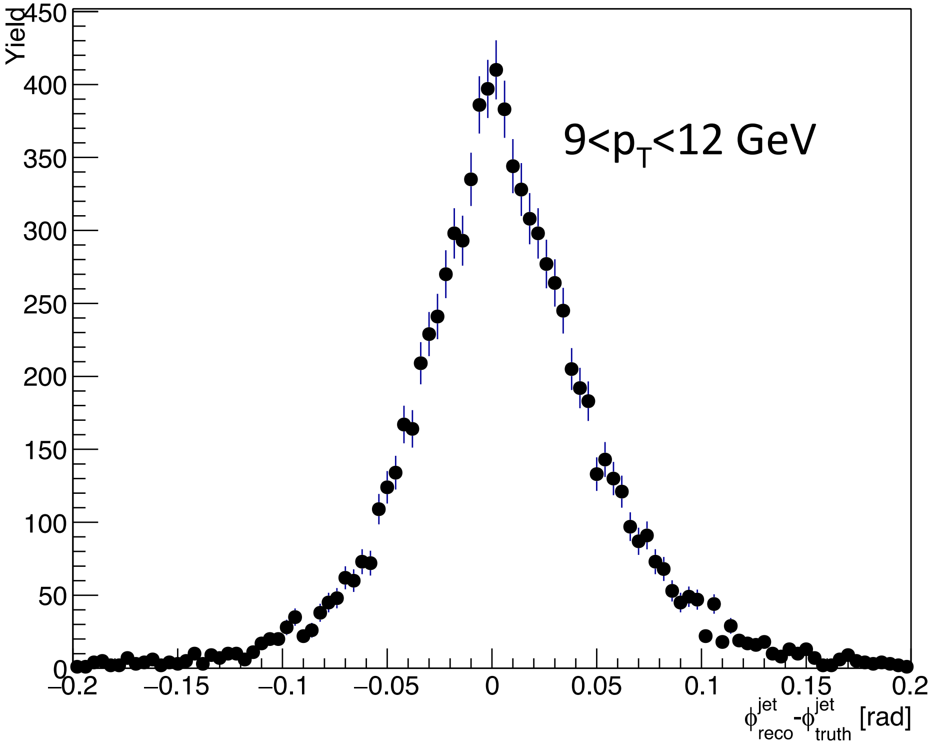




- Jet $p_T$ response is significantly worse at small $p_T$ (not surprising)
- At 9-12 GeV the response returns to the nominal mean+width of ~0.8±0.1 that was seen for $p_T^{jet}$>20 GeV from last presentation
- Indicates a limit for γ+jet measurements of ~12 GeV for the γ

# Jet ϕ Response

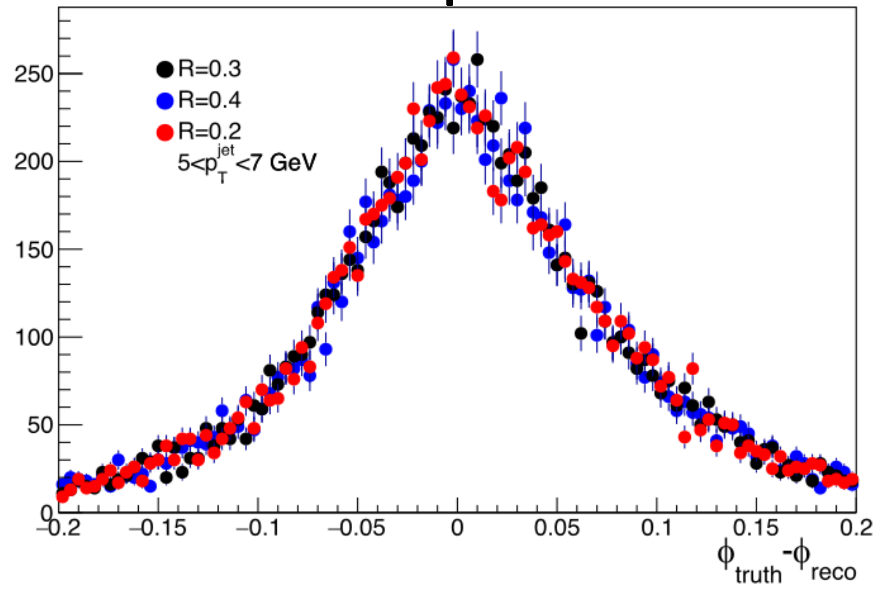


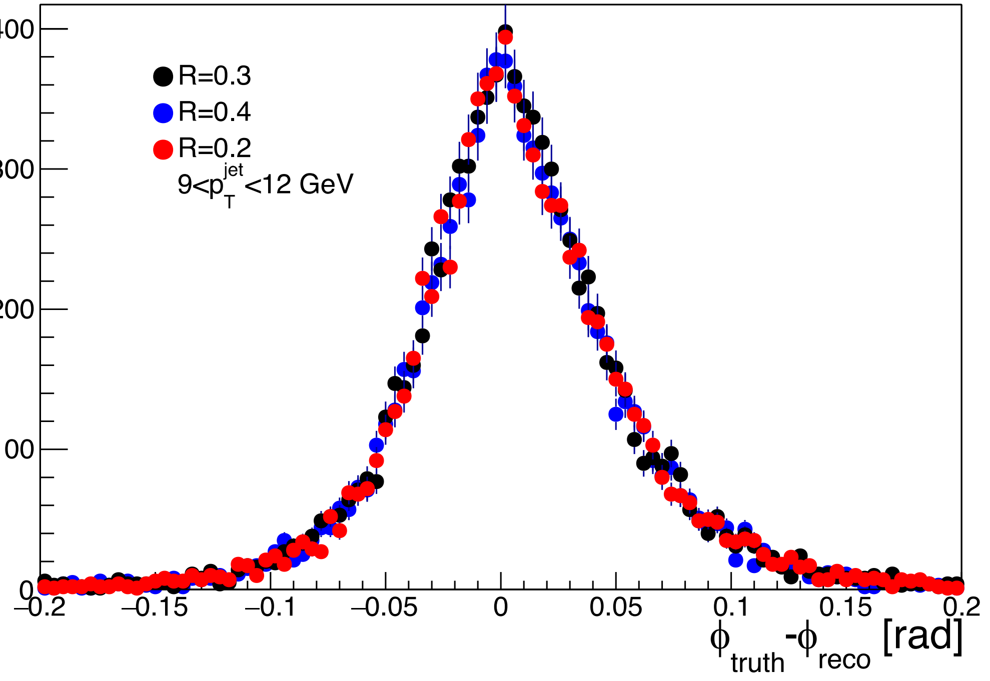



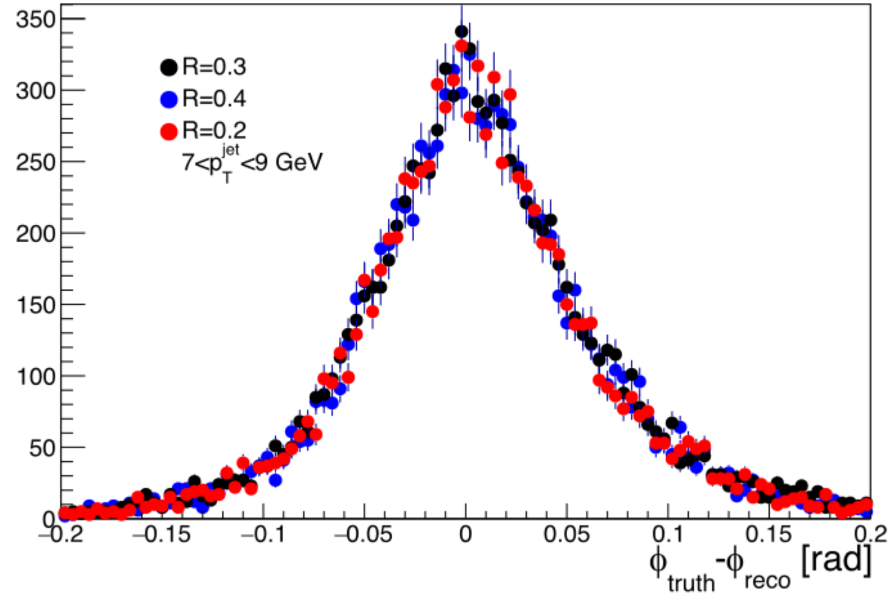




- In order to reliably determine $p_{out}=p_T^{jet}\sin(\Delta\phi)$ we need to also have good jet ϕ resolution
- This considerably degrades with jet $p_T$ also
- Further emphasizes the point that we need a jet of at least ~10 GeV

# Jet Response as a Function of Cone Size R



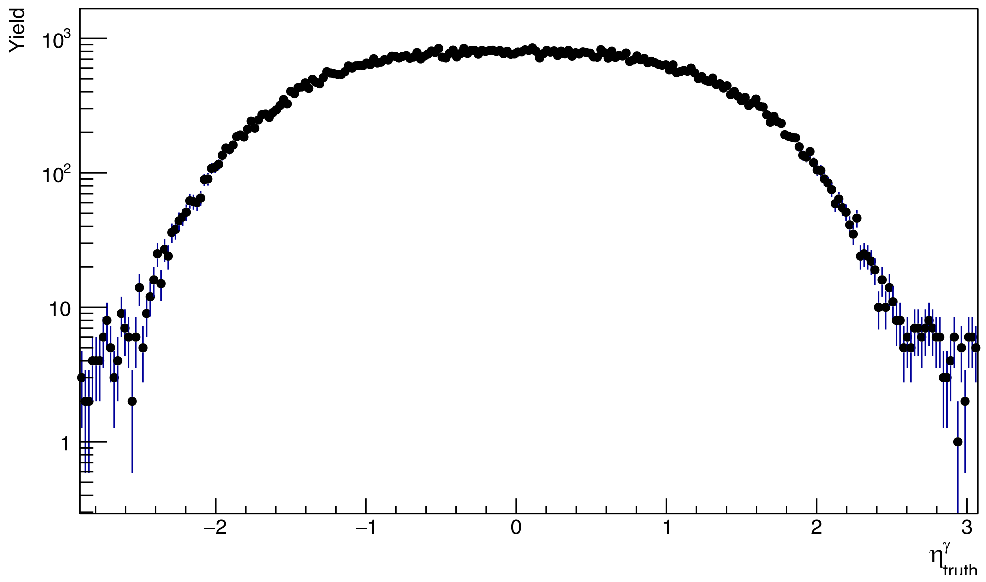



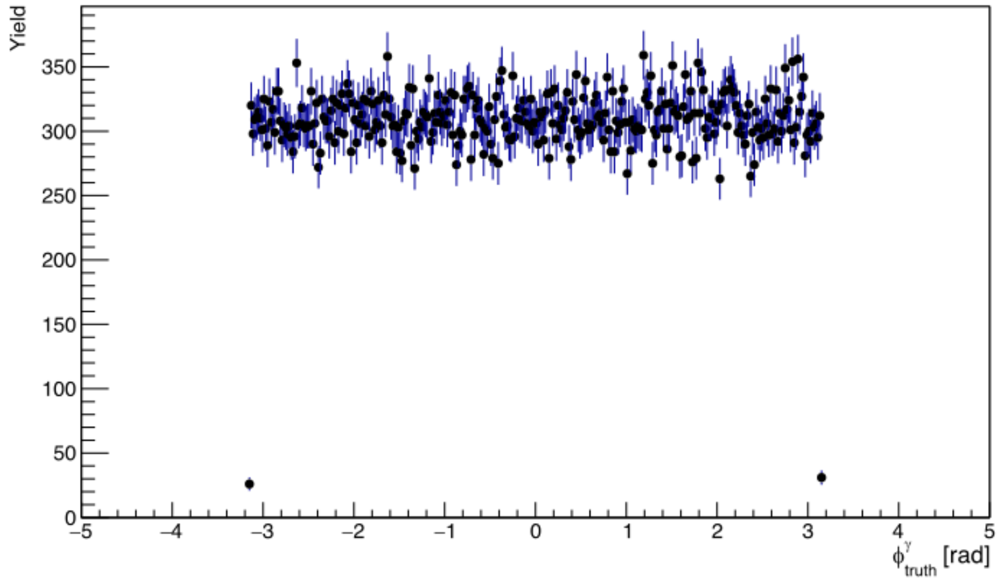



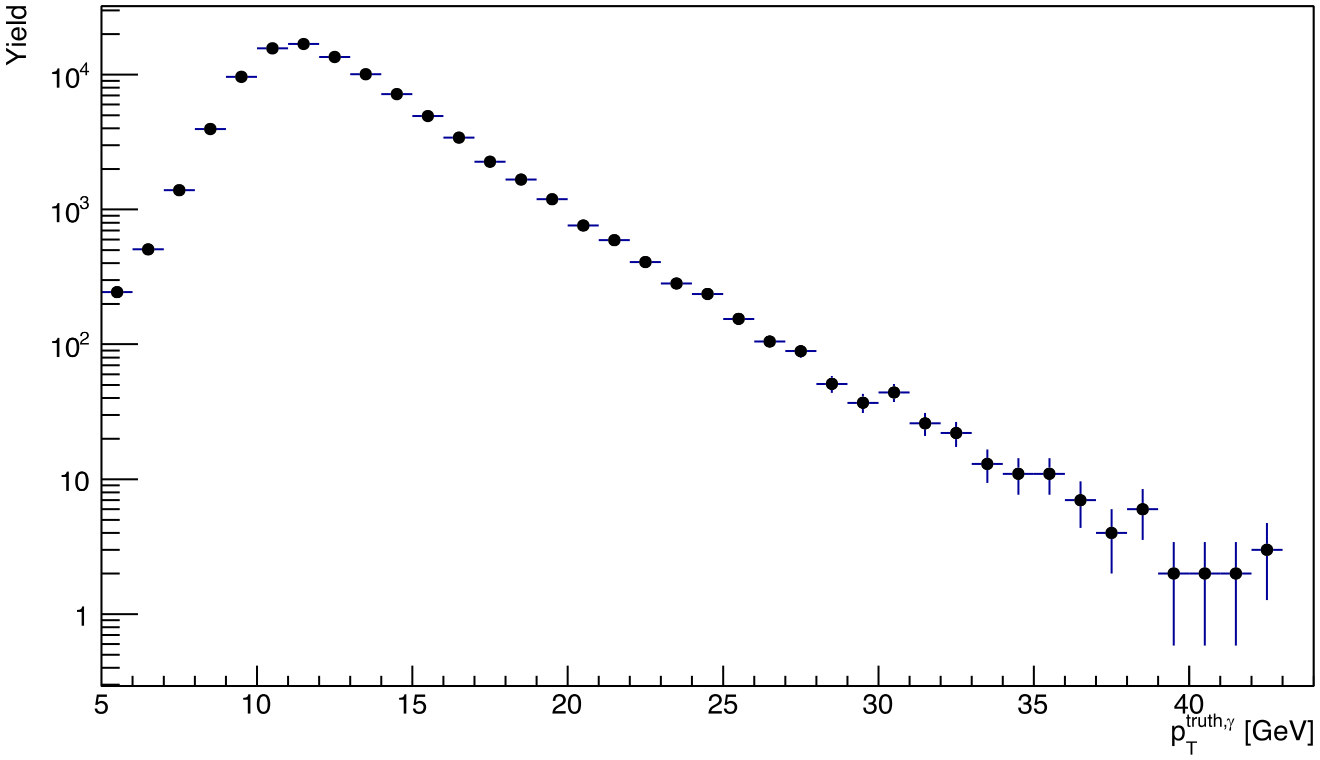

- Jet cone size does not change resolution of azimuthal angle
- Similar (non)dependence was found with $p_T^{jet}$ before Quark Matter (see backups)
- Indicates in pp collisions that jet is mostly defined by several hard collimated particles?

# Acceptance/Efficiency

# Truth Distributions



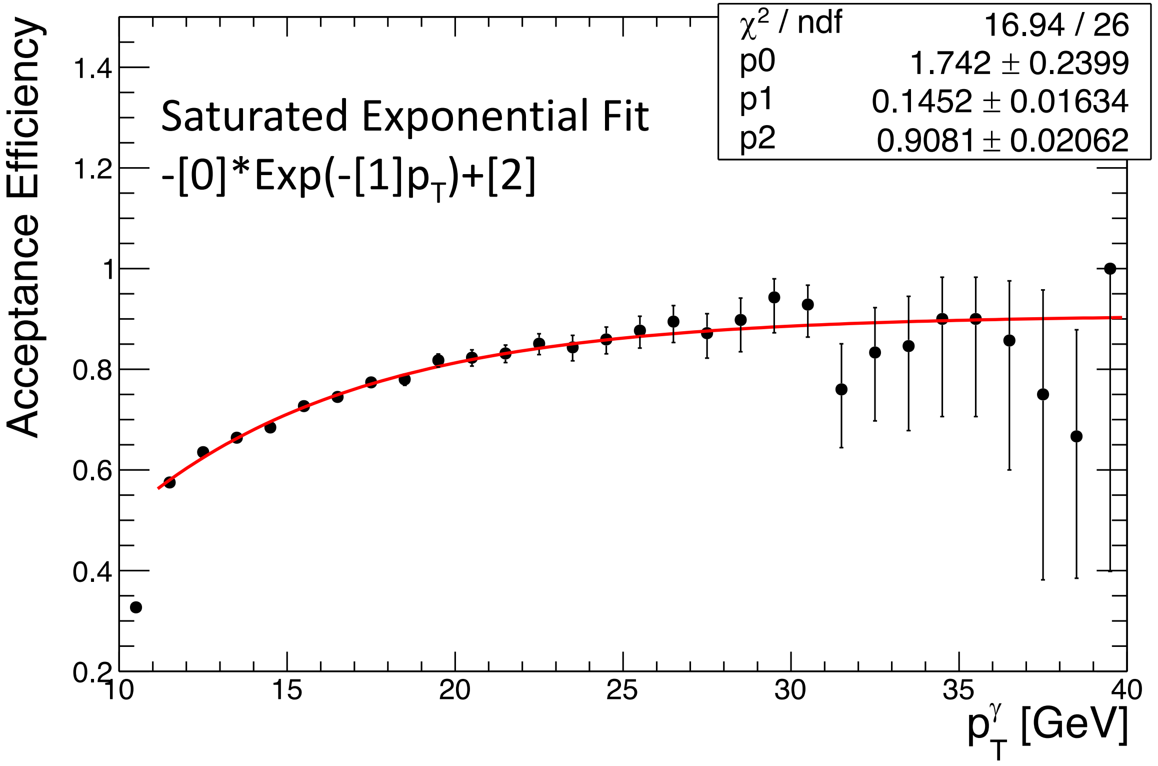




Truth distributions look as expected for the direct photon

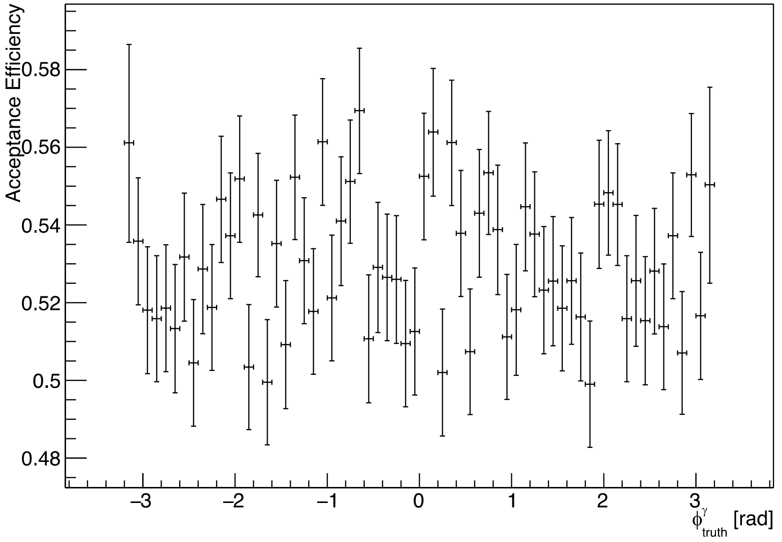
# Acceptance and Efficiency

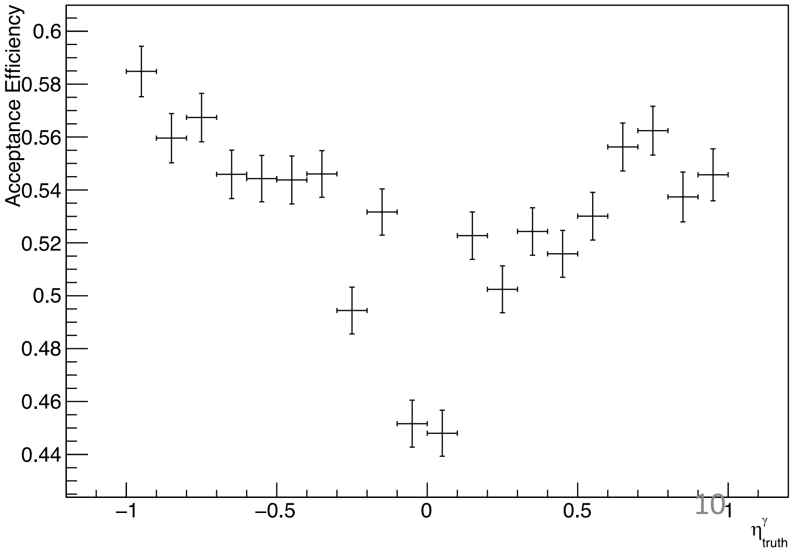
- Acceptance and efficiency determined for the sPHENIX acceptance only
- So really it is just an efficiency
- Defined as:

$$\frac{N_{reco}(p_T^{\gamma} > 10, p_T^{jet} > 5GeV)}{N_{truth}(p_T^{gamma} > 10, p_T^{jet} > 5GeV, |\eta| < 1)}$$




- Efficiency flat in ϕ; shows some detector effects in η

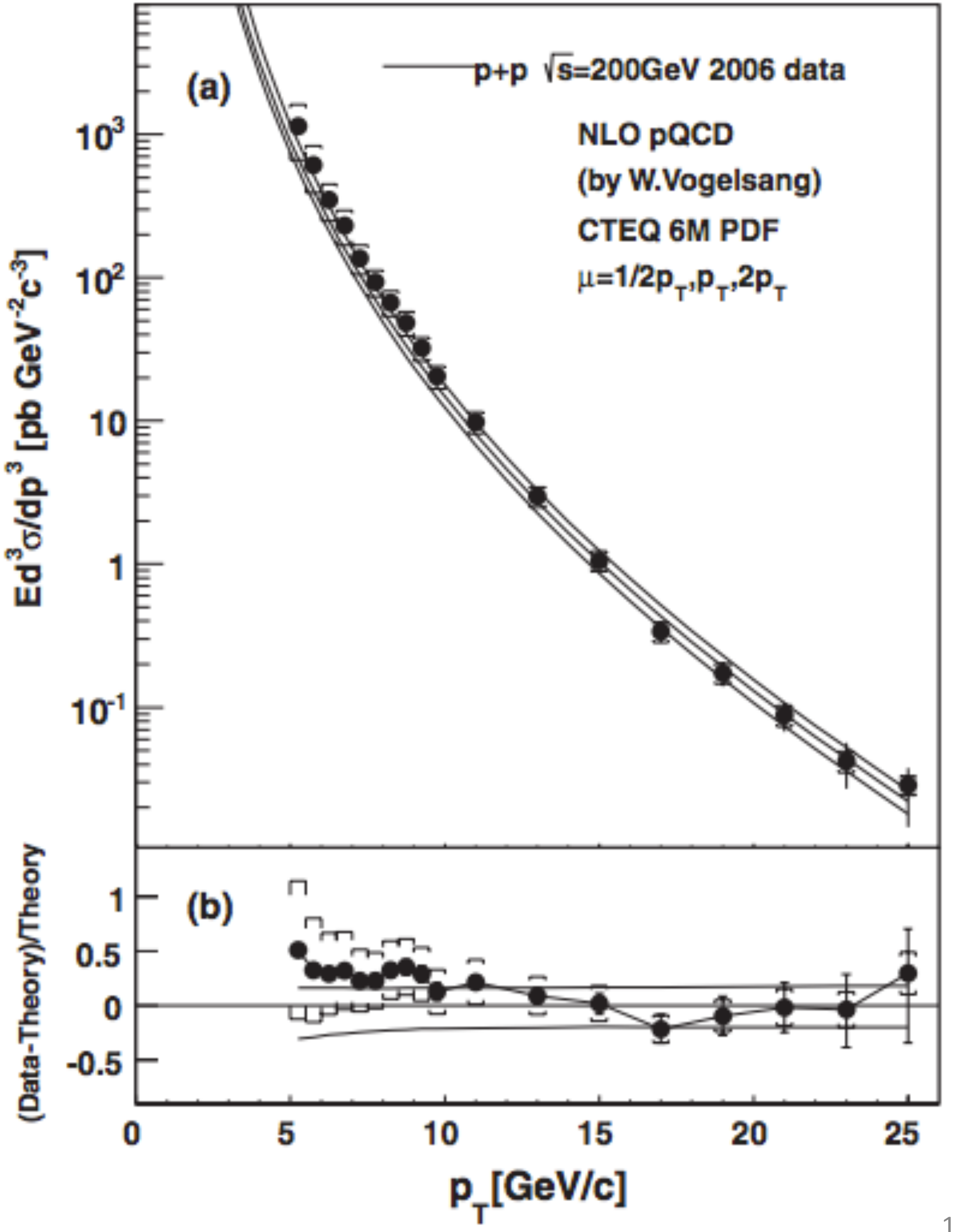


# γ-Jet Yield Estimate

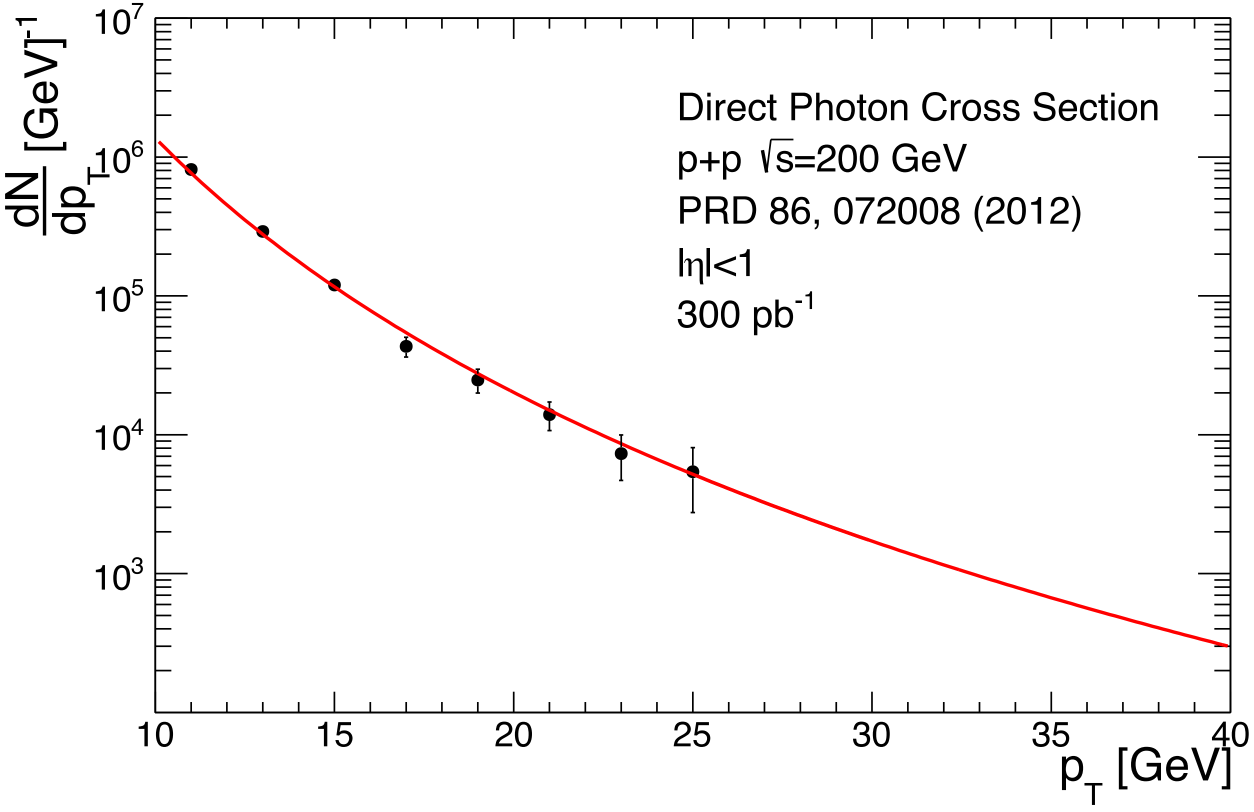
# Cross Section

- Unfortunately I can't find a γ-jet cross section at RHIC energies
  - Theorists probably skipped it since no detectors are capable of measuring it at RHIC
- So I used the direct photon cross section from PHENIX
  - Not exactly the same, but to first order every direct photon should have an away-side jet (just a question of if we measure the jet or not)
- Need to translate cross section to yields



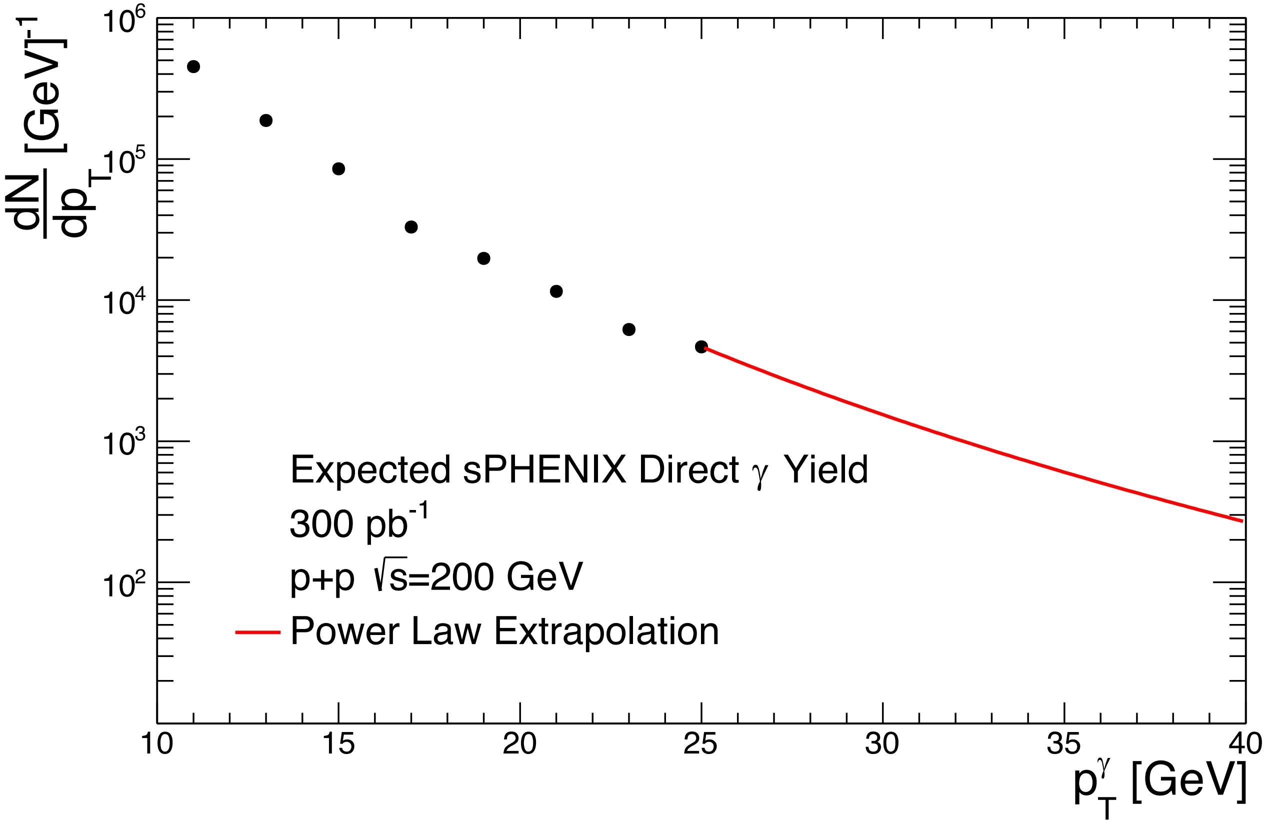
# Cross Section Yields

- Cross section translated to yields
- Yields are within $|\eta|<1$
- Fit to a power law to get the high $p_T$ dependence where we will be able to measure at sPHENIX
- Now to apply sPHENIX efficiency values



# Cross Section Yields + Acc/Eff

- Apply acceptance and efficiency values to the yields from previous page
- Quite a few direct photons!
  - The power law extrapolation is just the power law fit multiplied by the saturation term from the acceptance/efficiency fit
- Even if we assume some percentage of jet finding efficiency this is a good number of γ-jet over a large range of $p_T^\gamma$



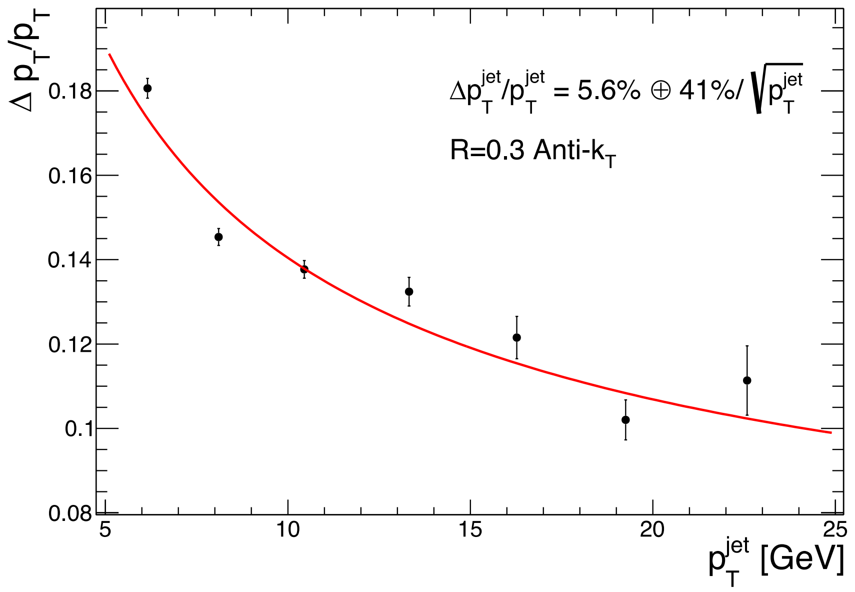
# Comparisons?

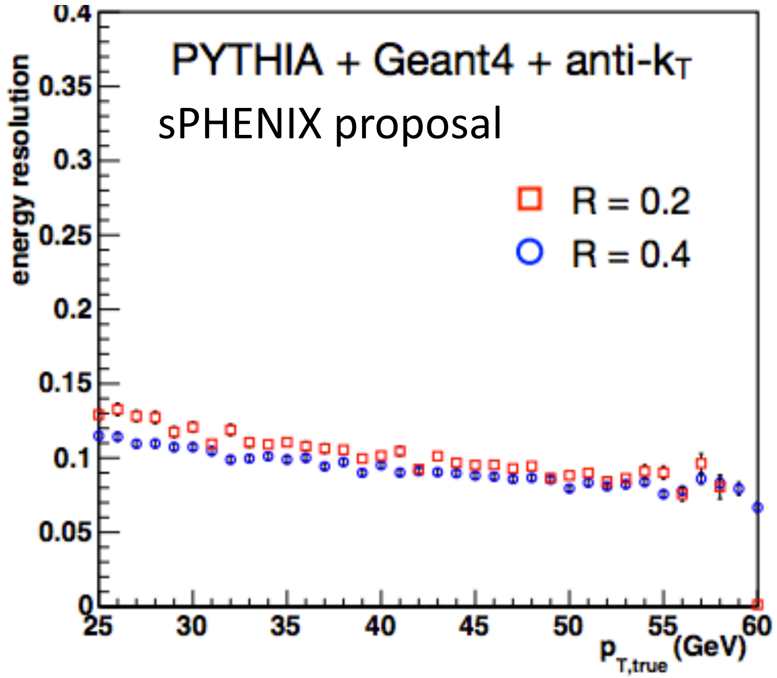
- Unfortunately I don’t see any γ-jet yield projections in the sPHENIX proposal document to cross check with
- Before acceptance and efficiency, seems to match the order of magnitude of expected γ-jets above 30 GeV according to Dennis Perepelitsa (~10k above ~30 GeV)

# Resolution of Observables

# Resolution Estimate on $p_{out}$ at sPHENIX

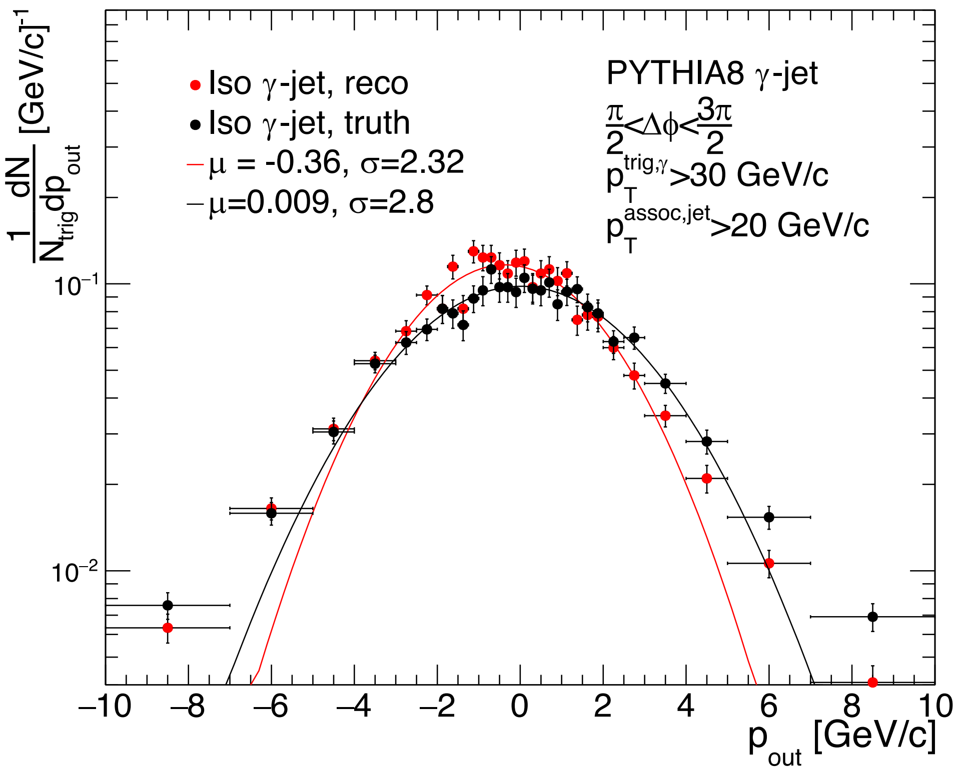
- To make a good γ–jet measurement of $p_{out}=p_T^{jet}\sin\Delta\phi$, we need good resolution on $p_T^{jet}$, and the azimuthal angles of the γ-jet
- $p_T^{jet}$ resolution from my simulations shown to the right
  - Note: don't believe the constant term, it is so small due to no data at higher $p_T$ to constrain fit. sPHENIX proposal shows that the resolution flattens out at ~0.1 (bottom right)
- We saw that the resolution on $\phi_{jet}$ ~0.06 rad
- The EMCal tower resolution is ~0.02 rad
- 0.08/π rad gives a ~3% resolution, so the $p_T$ term dominates the resolution

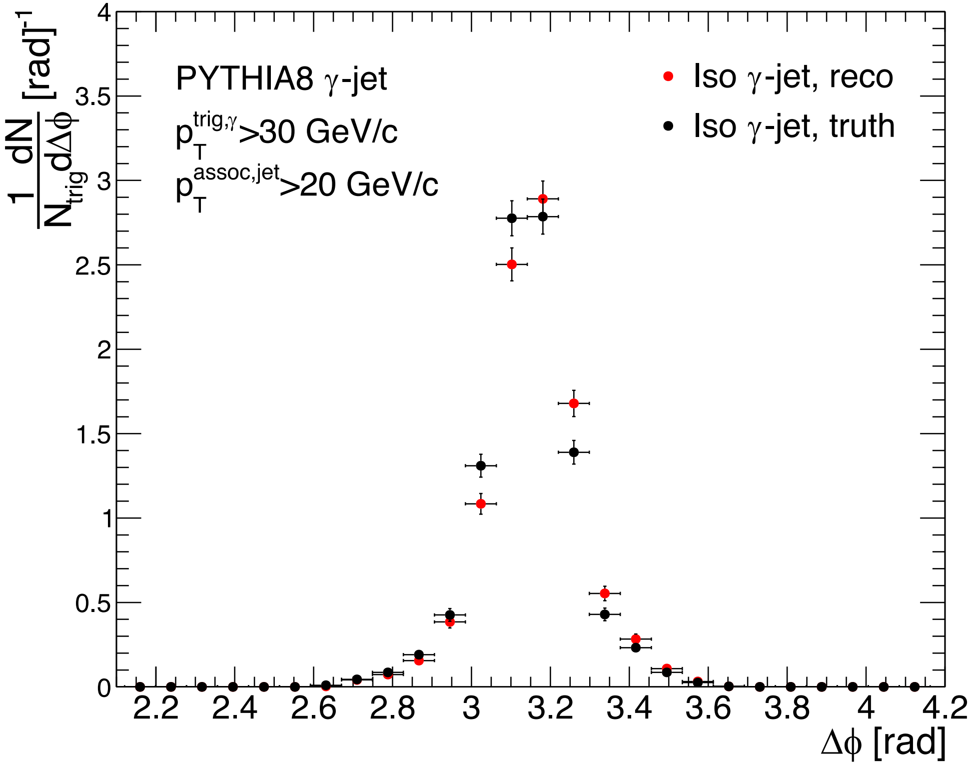


# Resolution Estimate of $p_{out}$ and $\Delta\phi$

- We saw that the nonperturbative widths are on the order of ~2 GeV
- Therefore we can construct $\Delta\phi$ bins and $p_{out}$ bins with widths of ~0.08 rads or ~0.2 GeV, which are fine enough to measure nonperturbative behavior



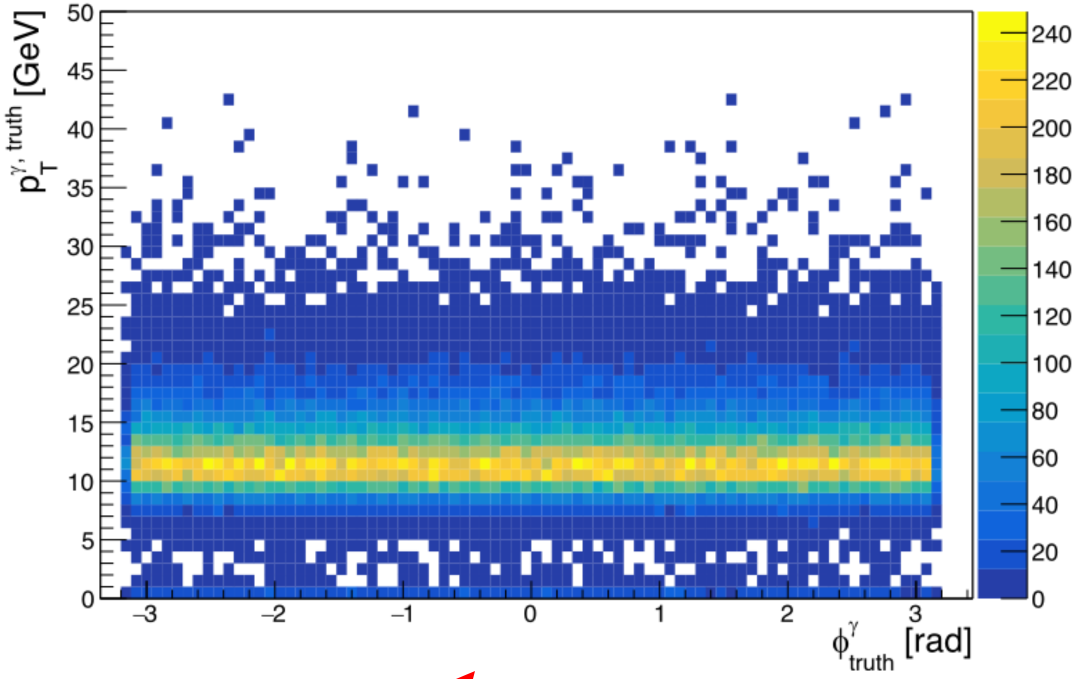
# Conclusions

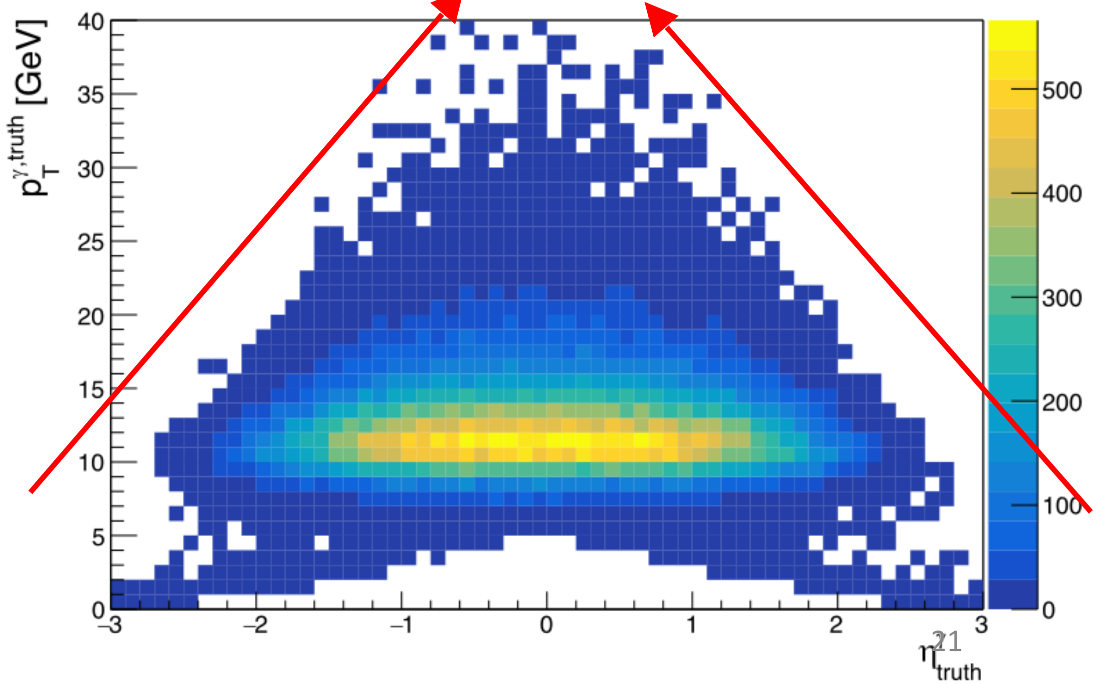
- Showed jet $p_T$ and $\phi$ resolution down to small jet $p_T$
  - Resolution degrades considerably, as expected. For making a good $\Delta\phi/p_{out}$ measurement, probably need to consider only photons >12 GeV so that the jet has $\gtrsim$ 10 GeV $p_T$ and thus reasonable resolution on $\phi,\eta,p_T$
- Acceptance/Efficiency correction constructed for γ-jet
- Obtained some yield estimate of direct photons for sPHENIX. Seems like we will have plenty to measure in the above $p_T$ range
- Resolution of current detector configuration should be sufficient to make good measurement differential in $\Delta\phi$ and $p_{out}$
- To-Do
  - Generate some set of PYTHIA files with number of γ-jets expected so that I can make some statistical precision estimate on physics observables

# Back Ups

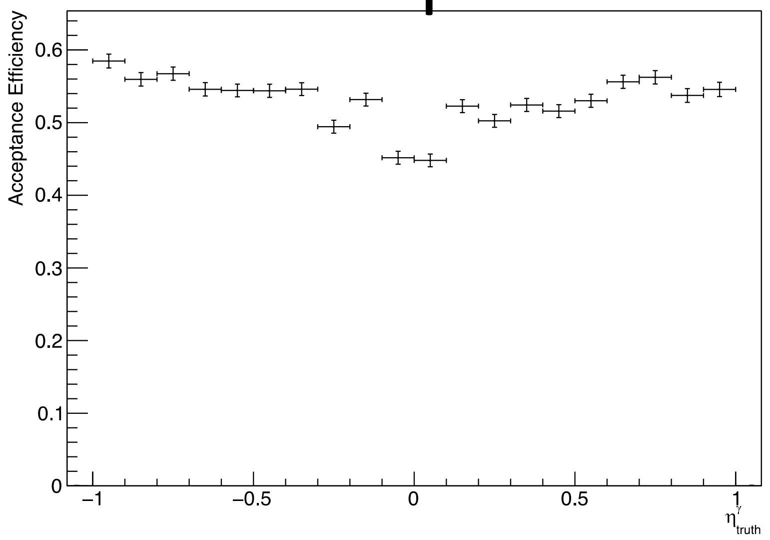
# Truth γ Distributions

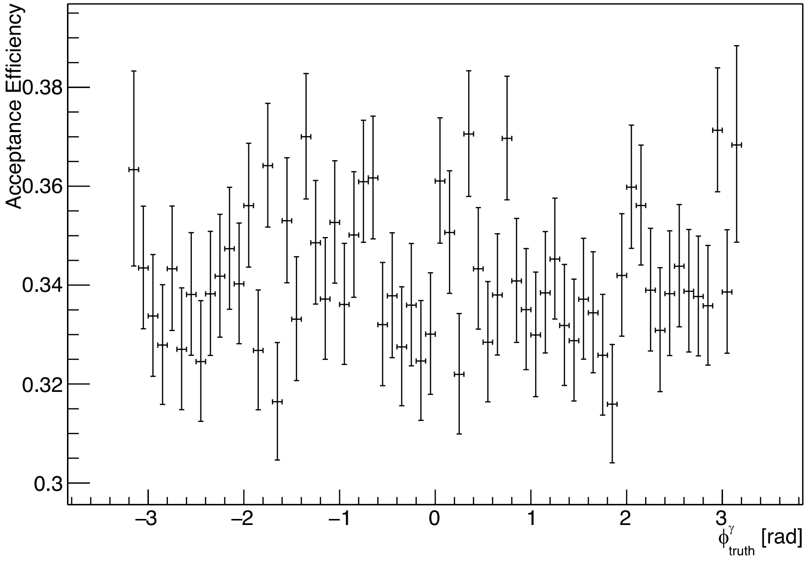
- η truth response is confined to |η| <1 at $p_T$>25ish
  - This matches the efficiency towards 1 with increasing $p_T$
- This also reinforces discussion with Stefan that the effect is from kinematics
- i.e. as $p_T$ increases one probes a larger x in the proton and thus is constrained kinematically to certain polar angle scatterings

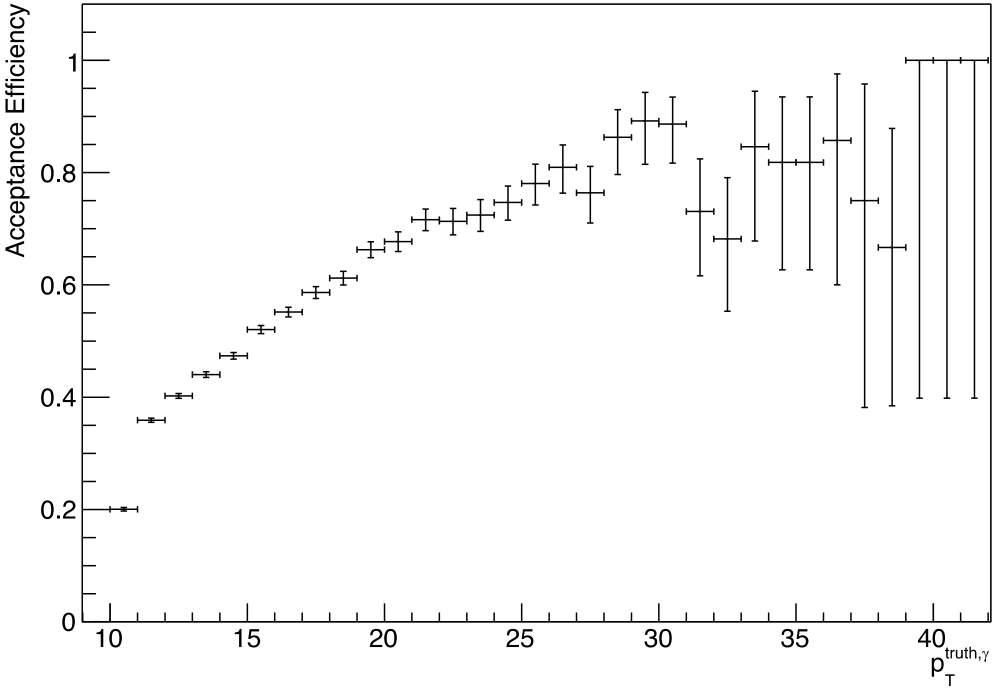


# sPHENIX Acceptance and Efficiency in Full Phase Space




- Here acceptance and efficiency is made in full phase space, so this is a true "acceptance and efficiency"
- i.e. there is no requirement that the truth photon-jet pair falls within |η|<1

# Cross Section to Yields

$$E\frac{d^3\sigma}{dp^3} = E\frac{d^3\sigma}{p_T d\phi dp_t dp_z}$$

- Changing the cross section values to yields
- Using integrated luminosity of 300 pb$^{-1}$ (RHIC Cold QCD Plan) arXiv:1602.03922

Using: $$\frac{dp_z}{E} = dy \qquad \int d\phi = 2\pi$$

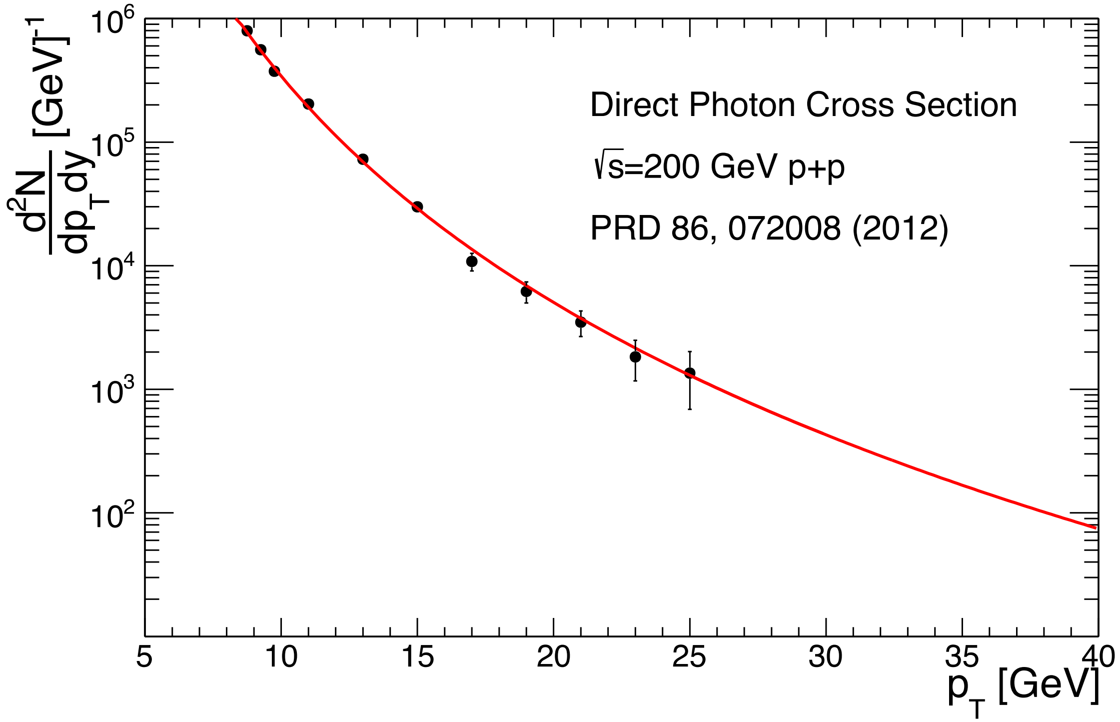
$$\Rightarrow \quad E\frac{d^3\sigma}{dp^3} = \frac{1}{2\pi p_T}\frac{d^2\sigma}{dp_T dy}$$

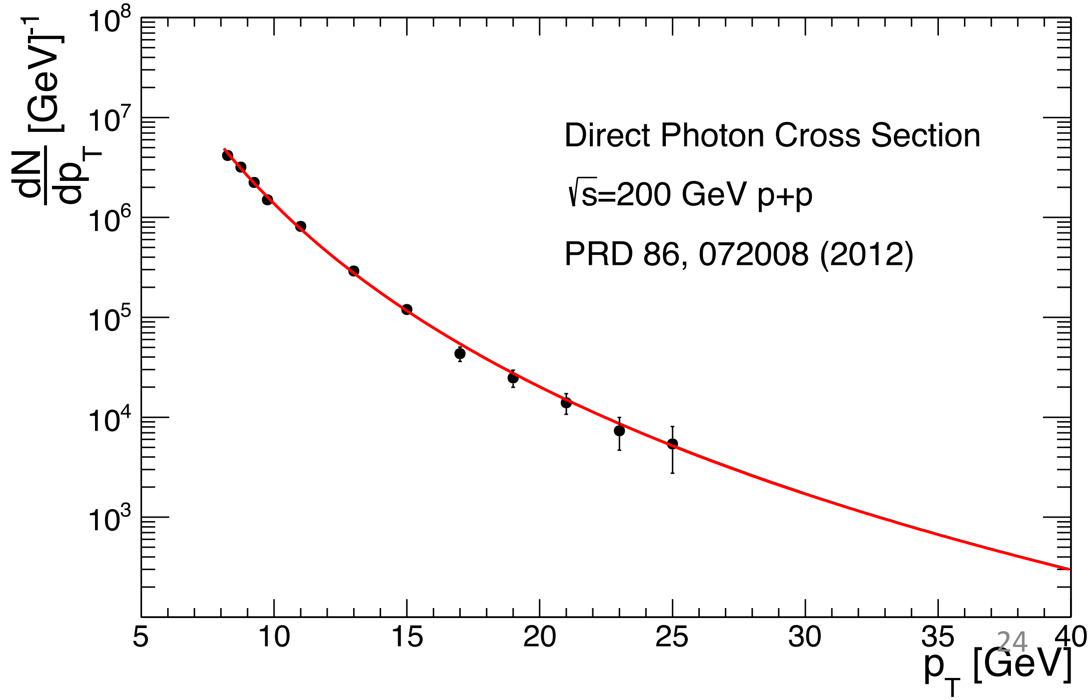
Therefore with: $N = \sigma\mathcal{L}$

$$\Rightarrow \quad E\frac{d^3\sigma}{dp^3}2\pi p_T\mathcal{L} = \frac{d^2N}{dp_T dy}$$

# Direct Photon Yields

- Applying the prescription on the previous page to the cross section points gives this (top right)
- PHENIX cross section measured in |η|<0.25
  - Not a typo, they used fiducial cuts
- So this means for sPHENIX this should be scaled by a factor of 4 (0.5η*4 = 2η) (bottom right)
  - PYTHIA shows cross section is basically flat between |η|<1
- This gives a reasonable match to what Dennis said: 10k γ-jets above $p_T$=30
  - Integral of power law fit [30-40 GeV] gives ~8000 total



# Jet $p_T$ Response with Cone Size

- Jet $p_T$ response largely unmodified by cone size used
- Indicates in pp collisions that jet is defined by several hard collimated particles
- Underlying event does not contribute much to jet characteristics